Appendix E
Pacific Fishery Management Council Fishery Modeling

Contents

To estimate changes in harvest, angler effort, and effects on listed and unlisted salmon stocks in the Pacific Coast area fisheries, a model was constructed to simulate hypothetical fisheries in each of four management areas—Canada-Cape Falcon, Cape Falcon-KMZ, Klamath Management Zone (KMZ), and South of KMZ—using the suite of status quo management measures and using mark-selective fisheries in combination with these other management measures under varying abundance conditions.

Two baseline period indices (Baseline 1 and Baseline 2) of abundance for key stocks were formulated. The base periods are not estimates of actual abundance but a representation of relative stock composition for purposes of calculating fishery impacts to different stock groups. Baseline 1 (based on 1988-1993 data) represents a fairly broad range of ocean survival conditions, with relatively high abundances of coho in some years and relatively low abundance in others. Baseline 2 (1994-1997 data) represents more recent conditions, with low abundance of many coho stocks, high abundance of chinook stocks from central California, and abundance of other chinook stocks similar to or lower than those of Baseline 1. Other demarcations could have been used for the base periods or a single base period could have been used. Choice of these timeframes was also logical from the standpoint that prior to 1992 there were no listed salmonid ESUs.

In general, Baselines 1 and 2 were formulated by using the average annual ocean escapement for key stocks of adult chinook and coho salmon added to the estimated catch of these stocks. Ocean escapement estimates were generally from Council Pre-Season I. Stock-specific catch estimates were based on Council catch data scaled by the best available stock contribution estimates. Table E-1 shows the specific method, data sources, and assumptions for the stocks used in the model. Table E-2 shows the chinook abundance indices used for fishery modeling for Baselines 1 and 2.

Relative abundance of adult salmon stocks for each of the four fishery management areas (FMAs) was calculated by partitioning the aggregate estimates. Several sources of information were used in this step. For the North of Falcon area, stock composition estimates from the FRAM “validation files” were used. For Central Oregon, both FRAM data and (unpublished) data from the Oregon Genetic Stock Identification study were used. In the KMZ and South of KMZ areas, stocks covered by the FRAM model are rarely taken. Existing models used to manage ocean salmon fisheries in these areas are the Klamath Ocean Harvest Model, the Central Valley Index, and the Sacramento Winter Run Chinook Index. Estimates for these two FMAs were made by NRC based on consultation with fishery managers from NMFS, ODFW, and CDFG. The two existing stock composition/abundance models most relevant to coho fisheries modeled are the Oregon Production Index (OPI) and the coho FRAM. There is some overlap of stocks covered in these models. Coho stocks were partitioned into OPI stocks, non-OPI stocks contained in the FRAM model, and non-FRAM stocks. An estimate of abundance for the north of Leadbetter area and south of Leadbetter area was made and further partitioned into the FMAs.

Table E-1. Calculation method, data sources, key modeling assumptions, and percent of stocks of naturally spawned origin used for abundance indices in fishery model.

Stock	Method / Data Source	Sources	Modeling Assumptions	% Natural B-1–B-2 (Source)
Chinook				
Sacramento Wi	Abundance =spawning escapement ÷ exploitation rate	Meyer et al. 1998	485 spawning escapement est. .54 exploitation rate est.	100% (1)
Central Valley Sp	Unknown		Not included in model	
Central Valley Fa	Central Valley Index	PFMC Pre-Season I Central Valley Index	Key assumptions are 96% contribution rate of this stock S. of KMZ, 75% in KMZ and 76% in Falc.-KMZ.	25% (2)
SONCC	Unknown		Not included in model	
U. Klamath & Trinity R.	Abundance = avg. inriver escapement + ocean catches.	Ocean abundance from PFMC I.1 Catch per Ocean Catch.ESU.	Key assumptions per Klamath Ocean Hvst. Model and Kaiser et al GSI work.	50% (1, 2)
OR Coast	Ocean escapement = 175,000 (avg spawning escapement)÷(1-.22) (avg inside expl. rate)	spawning escapement and exploitation: Meyers et al. p 214 for Catch from Kaiser et al. (unpublished)		10% (1,2,3)
WA Coast			Not included in model.	
Puget Sound	Ocean escapement + catch.	from PFMC Table I.1 based on avg of post-season estimates for years available. Catches based on chinook FRAM contribution estimates.	Key assumption, FRAM stocks have 98% contribution rate in Can.-Falc. catch, 7% in Falc.-KMZ, <2% in other areas.	28%-29% (1,4)
L. Col. R.	Ocean escapement + catch.	from PFMC Table I.1 based on avg of post-season estimates for years available. Catches based on chinook FRAM contribution estimates.	Key assumption, FRAM stocks have 98% contribution rate in Can.-Falc. catch, 7% in Falc.-KMZ, <2% in other areas.	20%-19% (4)
U. Willamette R. Sp	Ocean escapement + catch.	from PFMC Table I.1 based on avg of post-season estimates for years available. Catches based on chinook FRAM contribution estimates.	Key assumption, FRAM stocks have 98% contribution rate in Can.-Falc. catch, 7% in Falc.-KMZ, <2% in other areas.	10% (4)
U. Col. R. Su/Fa	Ocean escapement + catch.	from PFMC Table I.1 based on avg of post-season estimates for years available. Catches based on chinook FRAM contribution estimates.	Key assumption, FRAM stocks have 98% contribution rate in Can.-Falc. catch, 7% in Falc.-KMZ, <2% in other areas.	80%-69% (4,2)
U. Col. R. Sp	Ocean escapement + catch.	from PFMC Table I.1 based on avg of post-season estimates for years available. Catches based on chinook FRAM contribution estimates.	Key assumption, FRAM stocks have 98% contribution rate in Can.-Falc. catch, 7% in Falc.-KMZ, <2% in other areas.	35% (4,2)
Snake R. Fa		Sands and Koenings		100% assumed
Coho				
Oregon Coastal	OPI index	Ocean catch and escapement for OPI area from OPI index. Ocean catch for N. of Pt. Leadbetter based on FRAM contribution estimates.		11%-19% (5)
S. OR / N. CA	Not Estimated			
Columbia River	OPI index	Ocean catch and escapement for OPI area from OPI index. Ocean catch for N. of Pt.		0% (2)

Sources for natural stock composition:
1. Meyers et al. 2. NRC 3. ODFW 4. Council Pre-Season I 5. Oregon Production Index

Table E-2. Chinook abundance indices used for fishery modeling for Baselines 1 and 2.

Baseline 1

ESU Name	Ocean Escapements (000s) Natural	Hatchery	Total	Ocean Catch (000s) Natural	Hatchery	Total	Ocean Abundance (000s) Natural	Hatchery	Total
Sacramento Wi	0.4	0.0	0.4	0.5	0.0	0.5	0.9	0.0	0.9
Central Valley Sp	0.0	0.0	0.0	0.0	0.0		0.0	0.0	
Central Valley Fa	38.2	114.7	153.0	194.3	582.9	777.2	232.5	697.6	930.2
SONCC	0.0	0.0	0.0	0.0	27.6	27.6	0.0	27.6	27.6
U. Klamath & Trinity R.	108.1	108.1	216.3	11.9	11.9	23.8	120.0	120.0	240.0
OR Coast	201.9	22.4	224.4	4.0	0.4	4.5	205.9	22.9	228.8
WA Coast				0.0	0.0	0.0	0.0	0.0	
Puget Sound	36.0	92.6	128.6	8.1	20.8	28.9	44.3	113.2	157.5
L. Col. R.	32.4	129.8	162.2	13.1	53.3	66.4	45.0	183.6	228.6
U. Willamette R. Sp	10.0	90.3	100.3	0.5	4.1	4.5	10.5	94.3	104.8
U. Col. R. Su/Fa	142.8	68.8	211.6	7.0	1.8	8.8	175.8	44.6	220.4
U. Col. R. Sp	29.8	55.3	85.1	0.0	0.0	0.0	29.8	55.3	85.1
Snake R. Fa	1.1		1.1	0.2	0.0	0.2	1.8	0.0	1.8
Total	601.0	682.0	1,283.0	239.5	702.7	942.2	866.5	1,359.2	2,225.6

Baseline 2

ESU Name	Ocean Escapements (000s) Natural	Hatchery	Total	Ocean Catch (000s) Natural	Hatchery	Total	Ocean Abundance (000s) Natural	Hatchery	Total
Sacramento Wi	0.4	0.0	0.4	0.5	0.0	0.5	0.9	0.0	0.9
Central Valley Sp	0.0	0.0	0.0	0.0	0.0		0.0	0.0	
Central Valley Fa	66.9	200.8	267.8	194.3	582.9	777.2	261.2	783.7	1045.0
SONCC	0.0	0.0	0.0	0.0	27.6	27.6	0.0	27.6	27.6
U. Klamath & Trinity R.	112.8	112.8	225.6	11.9	11.9	23.8	124.7	124.7	249.4
OR Coast	201.9	22.4	224.4	4.0	0.4	4.5	205.9	22.9	228.8
WA Coast				0.0	0.0	0.0	0.0	0.0	
Puget Sound	65.8	86.7	152.5	8.4	20.5	28.9	52.5	129.0	181.4
L. Col. R.	46.2	60.8	107.0	12.8	53.6	66.4	33.3	140.0	173.4
U. Willamette R. Sp	16.7	22.0	38.7	0.5	4.1	4.5	4.3	38.9	43.2
U. Col. R. Su/Fa	87.1	114.8	201.9	6.1	2.7	8.8	146.3	64.3	210.7
U. Col. R. Sp	21.2	28.0	49.2	0.0	0.0	0.0	17.2	32.0	49.2
Snake R. Fa	1.1		1.1	0.1	0.0	0.1	1.4	0.0	1.4
Total	620.3	648.3	1,268.6	238.5	703.7	942.1	847.9	1,363.0	2,210.9

Notes:
Values are given in thousands.

The proportion of hatchery versus natural fish in each stock or ESU group was estimated from the Council Pre-Season Report I tables when those tables gave separate estimates of hatchery and natural runs or from estimates provided by fishery managers. Although a high percentage of the Snake River fall ESU is from hatchery origin, it was assumed that these fish would not be marked and they were treated as wild fish in the model. In aggregate, approximately 38 to 39 percent of chinook and 23 to 26 percent of coho present in Council-managed fisheries were estimated to be of naturally spawning origin.

Conservation objectives (expressed as ocean harvest rates or impact ceilings) in the current framework management plan for listed and unlisted stocks that are encountered in the fisheries were used as the overall limitations on fisheries. See Table E-3 for the most restrictive conservation objective for fisheries under Alternatives 1 and 2 for Baselines 1 and 2.

A sensitivity analysis in the model determined the most constraining conservation objective for each FMA which then became the limiting criterion for the modeled fishery. For instance, central Oregon fisheries were limited by harvest rate for OCN coho in some scenarios and Snake River fall chinook in others. See Table E-4 for key variables used in the Council fishery modeling.

Table E-3. Most restrictive conservation objective for fisheries under the Alternatives 1 and 2 for Baselines 1 and 2.

	Canada-Cape Falcon						Cape Falcon-KMZ					
	Baseline 1			Baseline 2			Baseline 1			Baseline 2		
	SQ	SA 1	SA 2	SQ	SA 1	SA 2	SQ	SA 1	SA 2	SQ	SA 1	SA 2
Reduce Snake River fall chinook impacts by 30% from base period.							X					
Continue 3% exploitation rate (approx.) on Puget Sound chinook ESU.		X	X		X							
Meet amendment 13 requirements for exploitation rate on OCN coho. *								X	X	X	X	X
Continue 5% (approx.) exploitation rate on Coastal and Puget Sound wild coho stocks.	X			X		X						

	KMZ						S. of KMZ					
	Baseline 1			Baseline 2			Baseline 1			Baseline 2		
	SQ	SA 1	SA 2	SQ	SA 1	SA 2	SQ	SA 1	SA 2	SQ	SA 1	SA 2
Meet inriver escapement goals for Klamath chinook.**	X	X	X	X	X	X						
Meet goal for 30% increase in cohort replacement							X	X	X	X	X	X

a/ Equivalent to approximately 20% exploitation rate for Baseline 1 and 13% for Baseline 2
b/ Equivalent to approximately 11% ocean exploitation rate.

Hypothetical fishing seasons were modeled for Alternatives 1 and 2. Alternative 1 used the suite of management measures specified in Tables 2.2-2, 4.3-1, and 4.3-2 in the FPEIS. The fishery constraints were harvest rates on species retained or incidental mortality on species released. Alternative 2 assumed fisheries were mark-selective, targeting the hatchery component of the runs and employing management measures used in Alternative 1 where they would further reduce impacts to weak or listed stocks. Fisheries were constrained by the incidental mortality of unmarked (natural) fish released in the fishery.

To calculate the harvest and the number of angler trips under each scenario, the model assumed commercial and sport catch rates would be the same as the base period. The model allowed commercial or sport fisheries to be open or closed at any given day between April 1 and October 30. Combinations of openings and closures were tested to produce the maximum fishing opportunity in terms of angler trips and maximum harvest value for commercial fishers.

Table E-4. Examples of key variables used in Council fishery modeling.

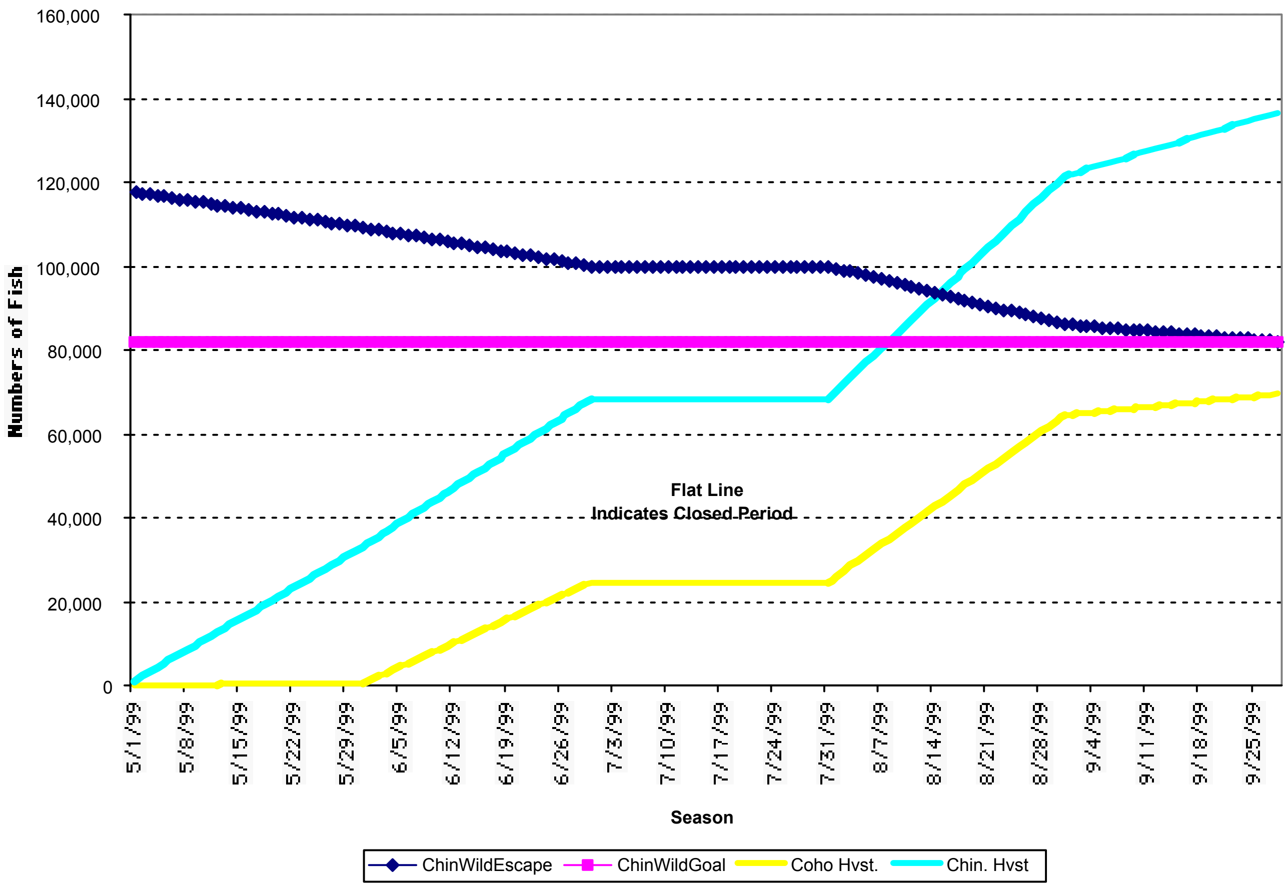
Examples of key variables used in PFMC fishery modeling for the Canada-Cape Falcon FMA

		May	Jun	Jul	Aug	Sep	Oct
Sport Coho CPUE		0.0	1.1	1.5	1.4	1.0	0.0
Sport Chinook CPUE		0.1	0.2	0.1	0.1	0.1	0.0
Troll Coho CPUE		0.0	0.0	24.5	31.3	31.6	1.0
Troll Chinook CPUE		11.5	13.1	7.8	2.9	3.2	1.7
Sport Effort		102.8	172.2	2369.4	1601.7	583.9	3.9
Troll Effort		89.1	54.4	38.0	76.3	27.2	0.9
Sport Season Open	(SQ Alt.)	no	no	yes	yes	yes	yes
Troll Season Open	(SQ Alt.)	no	no	yes	yes	yes	yes
Sport Season Open	(INT Alt.)	yes	yes	yes	yes	yes	yes
Troll Season Open	(INT Alt.)	yes	yes	yes	yes	yes	yes

	Status Quo	Intermediate
Selective Chinook Fishery	no	yes
Selective Coho Fishery	no	yes
Chinook Mark Rate	0	69%
Coho Mark Rate	0	69%
Troll Target Species	chinook	chinook
Troll Coho Retention	no	yes
Sport Target Species	coho	coho
Sport Encounter Rate Adjustment	no	no
Troll Encounter Rate Adjustment	yes	yes
Sport Coho Retention	yes	yes
Limiting Fishery	Chinook	Same
Chinook Driver Stock Limit	147	Same
Coho Driver Stock Limit		Same
Chinook Abundance Index	669,000	Same
Wild Chinook Harvest Rate	5%	Same
% Wild Chinook	27%	Same
Coho Abundance Index	1,719,000	Same
% Wild Coho	27%	Same
Wild Coho Harvest Rate	5%	Same
Wild Coho Escapement Goal	442,000	Same
Wild Chinook Escapement Goal	171,000	Same

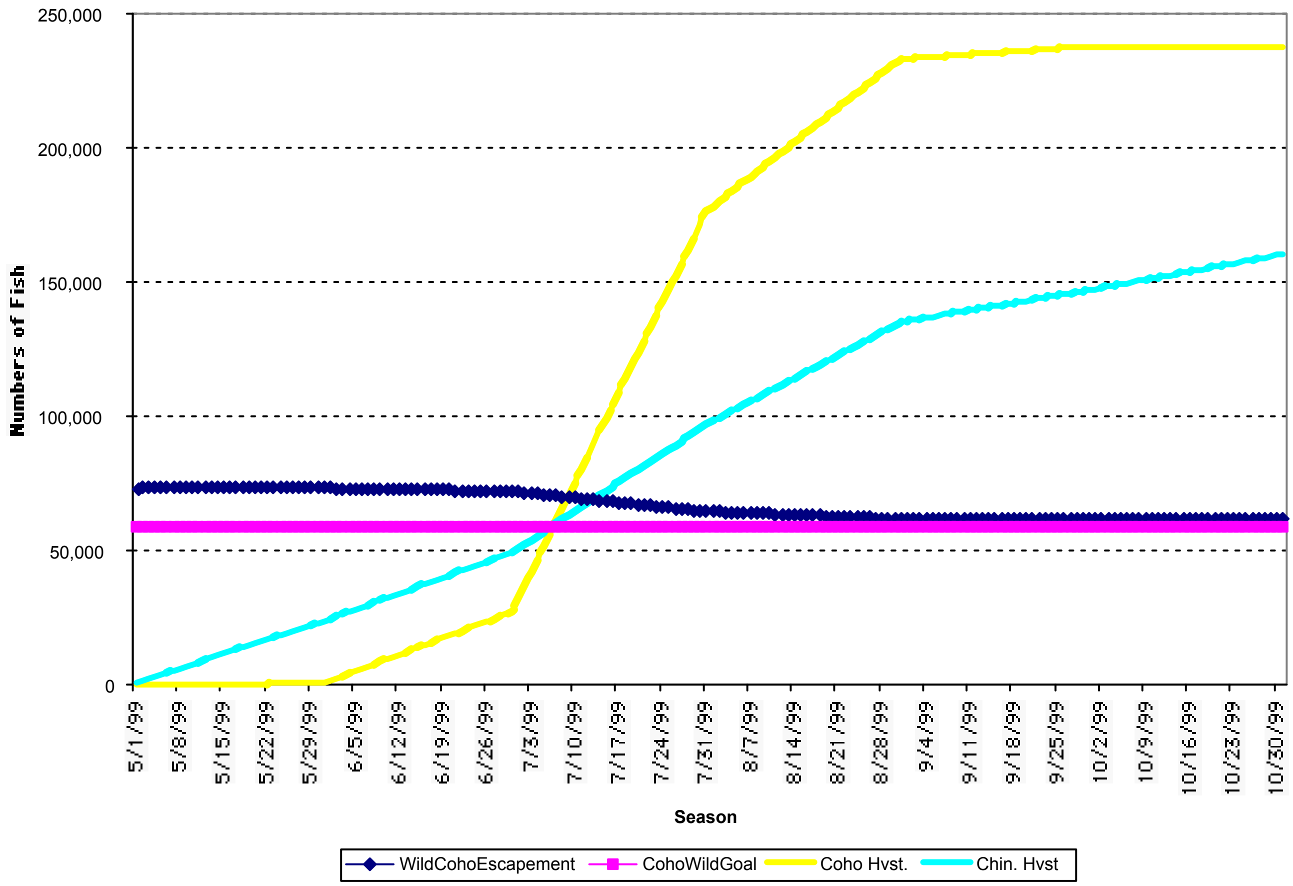
Figure E-1 shows a graphic representation of a fishery modeled using Alternative 1 for the Falcon-KMZ area for Baseline 1, Figure E-2 shows a fishery modeled using Alternative 2, Option A, for Falcon KMZ area for Baseline 1, and Figure E-3 shows a fishery modeled using Alternative 2, Option B, for the Falcon-KMZ area for Baseline 1, including open periods, coho and chinook harvest, escapement goal, and escapement. Flat areas in harvest trend lines indicated closed fishing periods. The fishery is limited by impacts on Snake River fall chinook, but the overall wild chinook escapement goal is used here because of chart scale.

Figure E-1. Example of a fishery modeled using Alternative 1 for the Cape Falcon-KMZ area for Baseline 1.



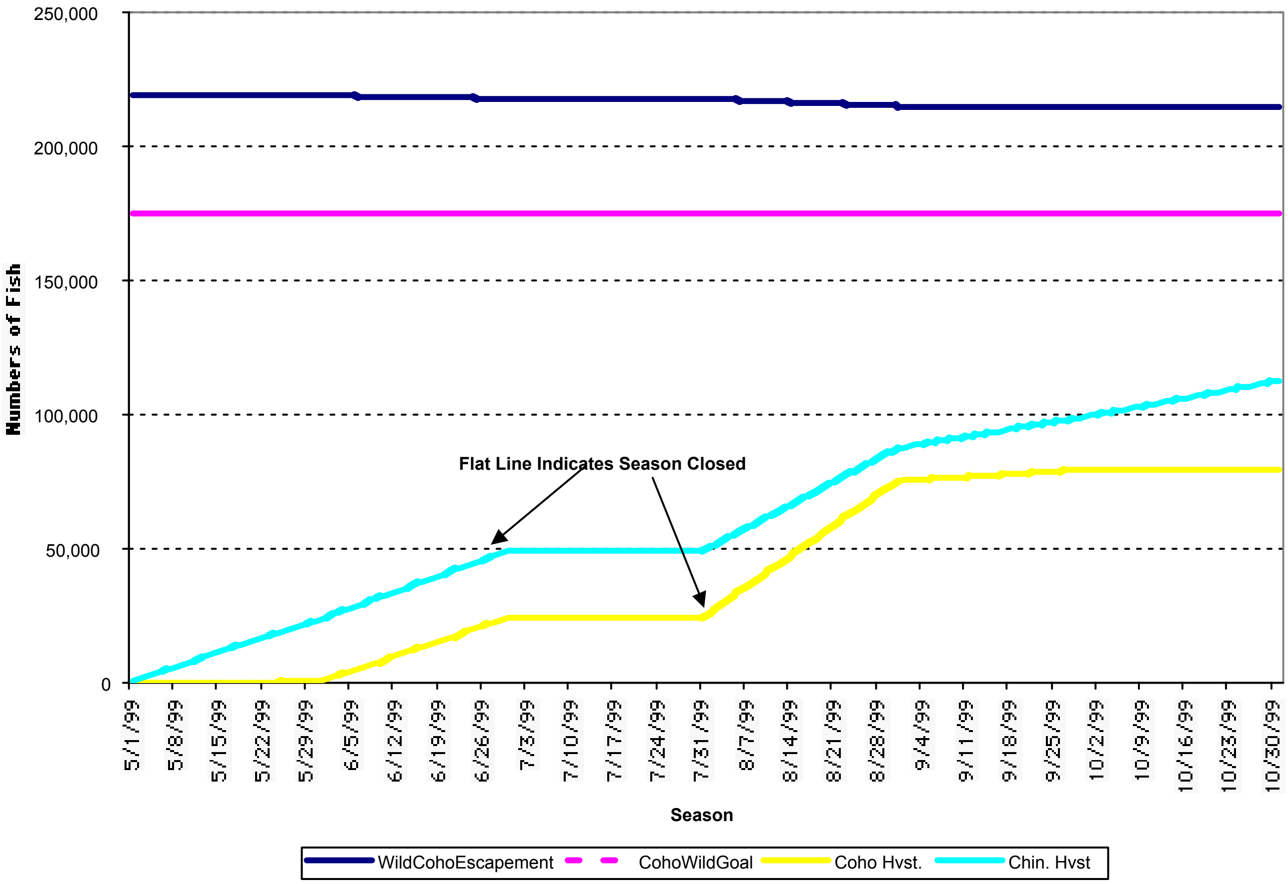
Notes:
Flat areas in harvest trend lines indicate closed periods.
Graph depicts coho and chinook harvest, and the escapement goal and escapement of wild chinook.

Figure E-2. Example of a fishery modeled using Alternative 2, Option A, for the Cape Falcon-KMZ area for Baseline 1.



Notes:
Flat areas in harvest trend lines indicate closed periods.
Graph depicts coho and chinook harvest, and the escapement goal and escapement of wild coho.

Figure E-3. Example of a fishery modeled using Alternative 2, Option B, for the Cape Falcon-KMZ area for Baseline 1.



Notes:
Flat areas in harvest trend lines indicate closed periods.
Graph depicts coho and chinook harvest, and the escapement goal and escapement of wild chinook.

E.1 Encounter and Incidental Mortality Rates

The viability of mark-selective fisheries as conservation tools depends on the proportion of the wild (unmarked) stock that dies as a result of being encountered, captured and released in a given fishery. This "incidental" mortality is the product of the encounter rate and the catch-and-release mortality rate.

The encounter rate for wild fish of the same species as the targeted hatchery fish will be equal to the proportion of the total stock which they comprise. For example, wild chinook are estimated to comprise about 24% of the chinook salmon in Pacific Coast fisheries. The encounter rate of a non-targeted species in a directed–species fishery depends on the relative abundance of the non-targeted species but may also be affected by the type of gear used and how it is deployed. For ocean fisheries targeting either chinook or coho, managers have devised regulations which take advantage the normal depth stratification of these two species, limiting gear deployment to shallower depths for coho and deeper depths for chinook.

Mortality occurring from catch-and-release has been studied for hook-and-line salmon fisheries for a number of years; however, there is considerable variability in the findings of different studies and uncertainty exists with regard to hooking mortality rates. The rates used in the analysis of impacts for the FPEIS were those stipulated by the Council for 1999 Pacific Coast fisheries (31% for commercial troll fisheries and 13% for sport fisheries, except in California waters, where sport hooking mortality is assumed to be 30%, owing to different gear and methods employed) and by the ADF&G for Southeast Alaska troll fisheries (21%).

Mortality rates associated with gillnets, purse seines, tangle nets, and fish traps have also been studied, but to a lesser extent. In a recent review of the literature, the Pacific Salmon Commission Chinook Technical Team recommended agencies use a 72% nonretention mortality rate for purse-seine landed chinook and a 90% mortality rate for gillnet-caught chinook. Some studies have shown much lower mortality rates with purse seine gear. In the analysis of mark-selective fisheries in the Columbia River, incidental mortality was assumed to be 10%, provided current gear restrictions for hook-and-line (recreational) fisheries were continued and gillnets were replaced by tangle nets, traps, weirs, dipnets, or other more benign gear.

Tangle nets are relatively small mesh (approximately 3.5 inch), nets which entangle fish by their teeth or mandible as opposed to traditional gillnets which entangle fish primarily by their operculae or gill structures. Tangle nets are a relatively new gear but initial tests show mortality of released fish to be much lower than gillnets. One study conducted in British Columbia showed immediate mortality of spring chinook to be less than 2%. Beach seines are long, relatively fine mesh nets which are deployed to encircle and confine salmon migrating near shorelines. Beach seines were commonly used in the Columbia River mainstem before the early 1900s and are frequently used by researchers because they tend to inflict little mortality if used correctly. Traps were commonly used to capture salmon in the Columbia River, Puget Sound, and Alaska until outlawed in the early 1900s.

While the researchers do not have information on nonretention mortality for traps, weirs, or dipnets, mortality rates for these gears are assumed to be less than or equal to 10%. This assumption is based on the observation that most nonretention mortality for salmonids results from wounds from hooks, net mesh entangling the gills, or from crushing (as in the case of purse seining). Provided handling is minimized, traps, weirs, dipnets, and similar methods have the potential to capture salmon with minimal physical trauma.

E.2 Incidental Mortality of Immature (Sublegal) Salmon

In many commercial and recreational fisheries, minimum size limits are employed to limit the harvest of smaller (immature) salmon. Because these smaller (sublegal) fish are not retained, the frequency of their encounter in fisheries must be estimated directly through field studies or indirectly through other means. Because impacts on sublegal salmon are not used consistently to define conservation objectives in the fisheries analyzed, sublegal impacts were not used in the fishery modeling and the model understates the total mortality of both hatchery and wild chinook. Encounter of juvenile coho salmon in Council-managed salmon fisheries is relatively infrequent, owing to the fact that the coho's marine residency is limited to approximately 18 months and that the fishery occurs at times, and in areas, where mature coho are feeding and/or migrating toward their spawning grounds. With chinook salmon, which spend several years in salt water, substantial numbers of immature fish may be encountered. One recent study of commercial trollers off Oregon showed approximately 0.5 sublegal chinook were encountered for every 1.0

chinook landed. Sublegal chinook encountered are typically 2-year-old fish and, because non-fishing mortality between ages two and three is typically high, managers adjust mortality of these fish in terms of adult equivalency to more accurately reflect the impact of incidental mortality. In general a factor of 0.50-0.60 is used; that is, between 40 percent and 50 percent of age two fish will die of non-fishing causes before they mature; thus, for every sublegal chinook encountered there would be approximately 0.17 adult mortalities (1.0 x 0.55 x 0.31 = 0.17). If the troll fisheries encounter 0.5 sublegal chinook for each legal chinook, the sublegal mortalities would be 0.085 "adult equivalent" mortalities for each chinook encountered.

An encounter of juvenile salmon in Columbia River fisheries is relatively rare, except for precocious fish, which sexually mature at a younger age and smaller size than others.

E.3 Mark Rates

In order to accommodate the "double index" tagging methodology necessary to maintain continuity of the coded wire tag (CWT) database (see Section 4.5), a portion of hatchery fish would need to remain unmarked; thus, 95 percent of hatchery fish were assumed to be marked in the model. See Table E-5 for a relationship between the encounter rate, mortality rate, and mortalities in a mark-selective fishery.

Table E-5. Relationship between encounter rate, mortality rate, and mortalities in a mark-selective fishery and effort and harvest in selective and non-selective fisheries limited by a harvest ceiling and limited by time.

Non-target fish captured per target fish landed	Capture and release mortality rate	Non-target mortalities per target fish landed
0.75	0.75	0.56
0.65	0.65	0.42
0.55	0.55	0.30
0.45	0.45	0.20
0.35	0.35	0.12
0.25	0.25	0.06

Effort and harvest in a non-selective and selective fishery
with a 10,000 fish incidental mortality ceiling

	Non-Selective Fishery	Selective Fishery
Wild Impact Ceiling	10,000	10,000
Wild:Hatchery Ratio	0.35	0.35
CPUE (e.g. troll fishery)	25	25
Hooking Mortality	1.00	0.25
Possible Effort (vessel days)	1,143	4,571
Hatchery Harvest	18,571	74,286
Wild Harvest	10,000	0
Total Harvest	28,571	74,286

Harvest and incidental mortality impacts on wild stocks in non-selective
and selective fisheries of set season length

	Non-Selective Fishery	Selective Fishery
Wild:Hatchery Ratio	0.35	0.35
CPUE (e.g. troll fishery)	25	25
Hooking Mortality	1.00	0.25
Effort (Season Length 20 days * 500 vessels)	10,000	10,000
Hatchery Harvest	162,500	162,500
Wild Harvest	87,500	0
Total Harvest	250,000	162,500
Wild Impacts	87,500	10,000
Savings in Wild Impacts		77,500